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GB 2248987 A GB 2145678 A GB 2078028 A
GB 1590290 A GB 1015225 A WO 87/04276 A1

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(54) Thermal protection for electric motor

(57) An electric motor 20 such as an A.C. motor with an integral fan blade 28, used in a power appliance (e.g. a drill), is protected should its temperature exceed a predetermined safety threshold. A first diode 36 inhibits conduction of negative half cycles of the A.C. power while permitting conduction of positive half cycles; this reduces the power to prevent further overwork, while permitting limited operation of the motor to continue fan cooling. A thermally operated bypass switch 46 bypasses the first diode when the temperature is below the threshold. A series connection of a second, opposite polarity, light emitting diode 42 and a current limiting/voltage dropping resistance 44, is connected in parallel with the first diode to provide a visual indication of status. The speed of the motor may be controlled by a triac (54, Fig. 4). The motor may be a D.C. motor driven by continuous D.C. or pulse modulated D.C..

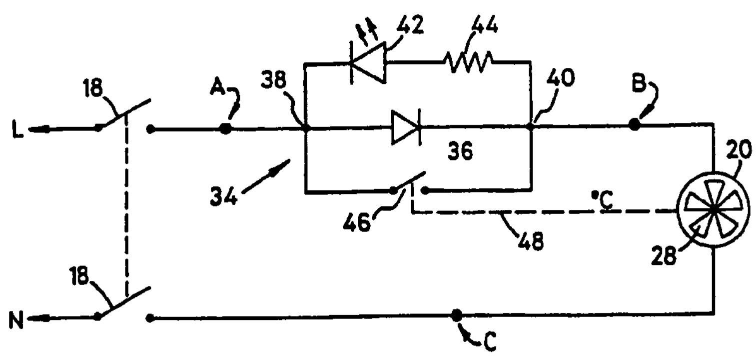

Fig. 2

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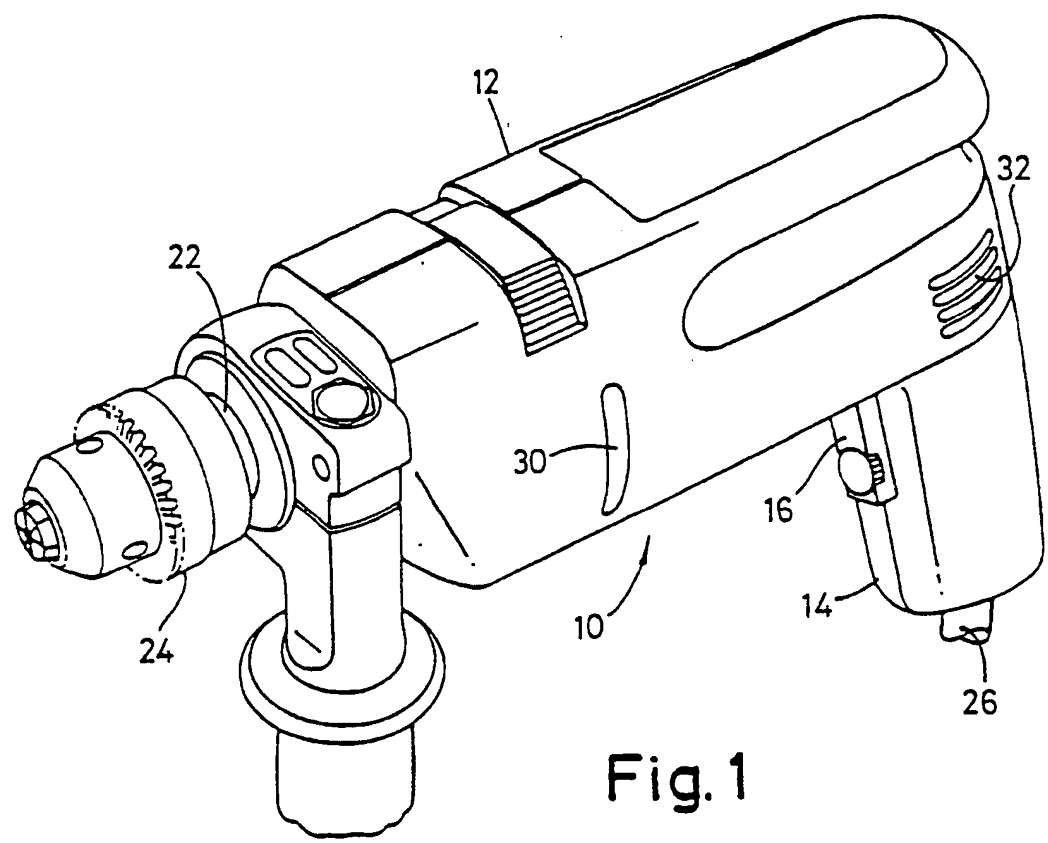

Fig. 1

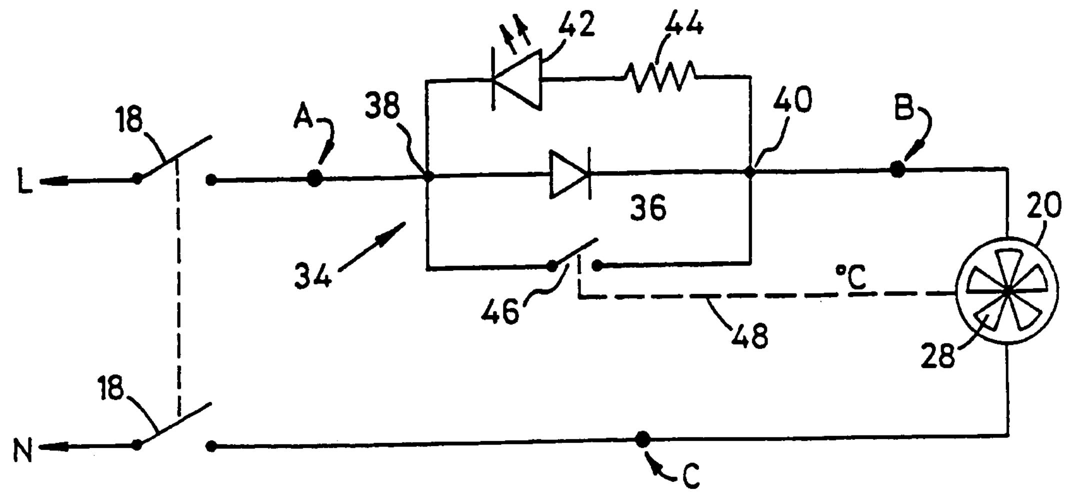
42
44
18
A
38
40
B
L
36
20
34
°C
46
48
28
18
N
C

Fig. 2

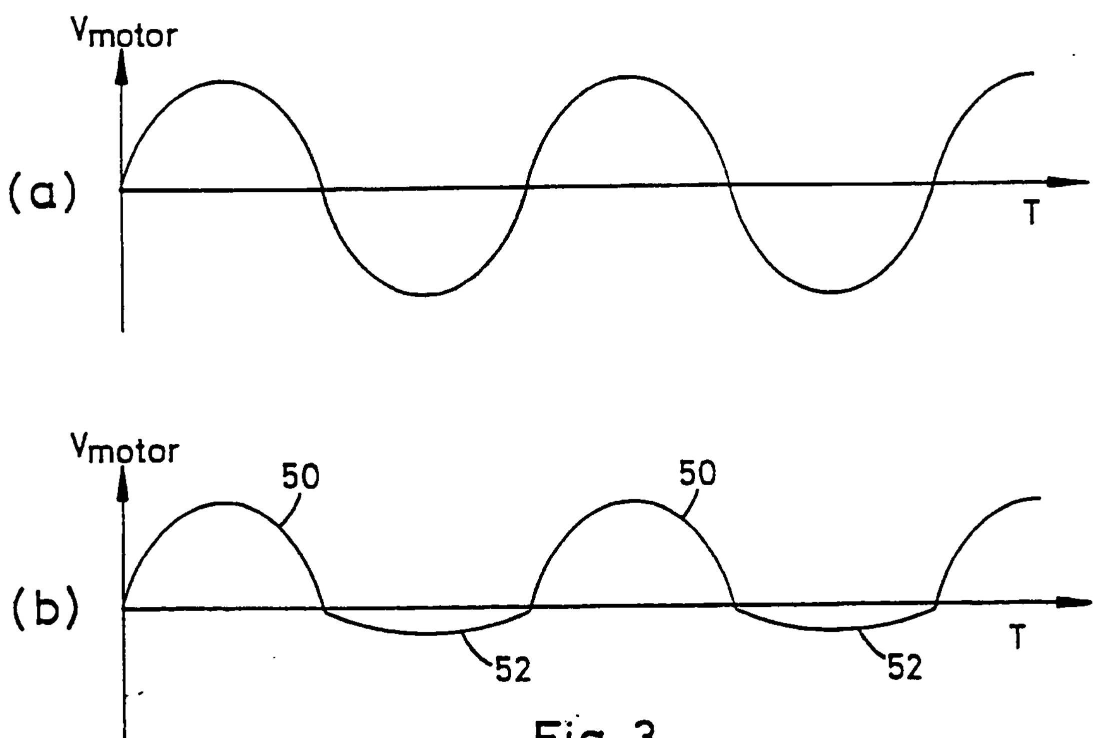
Vmotor
(a)
T
Vmotor
50
50
(b)
T
52
52

Fig. 3

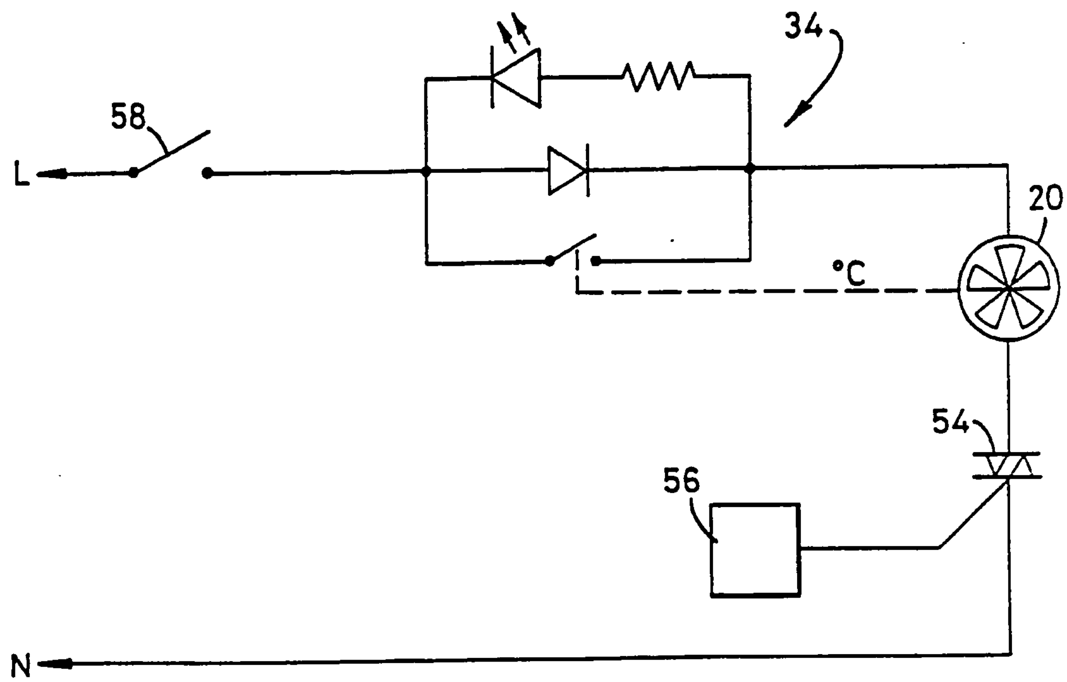

Fig. 4

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THERMAL PROTECTION FOR ELECTRIC MOTOR

This invention relates to thermal protection for an electric motor. The invention is particularly suitable for use in power appliances employing electric motors, such as power tools (e.g. electric drills and electric sanders), lawnmowers and the like.

In a first aspect, the invention provides an assembly comprising an electric motor and thermal protection apparatus for the motor, the apparatus comprising means for sensing a temperature associated with the electric motor and for detecting when the temperature exceeds a predetermined threshold, and means responsive to a detected excessive temperature for reducing the level of electric power supplied to the motor, the reduced level of power being intended to avoid further overheating but being sufficient to permit at least limited operation of the electric motor.

We have appreciated that even if a motor becomes overheated through overloading (ie. overwork), the motor can still be used safely for light loads. This is provided that the motor does not continue to generate more heat, and that the existing heat is permitted to dissipate. The present invention therefore operates to reduce the electric power supplied to the motor in the event of an overtemperature condition, to ensure that the motor is incapable of performing further heavy work.

Preferably, the motor includes means for cooling the motor as the motor operates. Such means may comprise a fan blade carried on, or operated by, the motor shaft. The fan blade blows air through the motor casing or body, or extracts air from the motor casing or body, in order to produce a cooling air draught. We have appreciated that when such a motor overheats, the heat can be dissipated more effectively by running the motor with only a light load or with no load, than by simply leaving the motor to stand at rest. Therefore, the present invention is particularly advantageous in enabling such a motor to continue to operate

in the event of an overtemperature condition, while preventing further overwork.

Preferably, the apparatus further comprises means for restoring the normal electric power supply level to the motor when the means for sensing the temperature detects that the temperature has dropped below the predetermined threshold. This provides automatic resetting of the thermal protection apparatus once the over-temperature condition has passed.

In the preferred embodiment, the means for sensing temperature comprises a thermally operated switch. The switch is activated from a first condition when the temperature is below the predetermined threshold, to a second condition when the temperature exceeds the threshold. The switch returns to the first condition (subject to any internal hysteresis) as the temperature again drops below the predetermined threshold. The switch is mounted in or on the motor in close thermal contact with the fixed field windings of the motor.

Preferably, the thermally activated switch is used as a bypass switch to bypass a permanent power reducing means, the bypass switch bypassing the power reducing means when the temperature is below the threshold.

The motor may be a D.C. motor driven by continuous D.C. or by pulse modulated D.C. Alternatively, the motor may be an A.C. motor. In the case of an A.C. motor or a pulse modulated D.C. driven motor, the means for reducing the electric power supplied to the motor preferably comprises means for reducing the "power-on" portion or duty cycle of the electric power being fed to the motor. For example, the power reducing means may inhibit or restrict conduction of every Nth pulse or conduction portion of the electric power signal, where N = 2, 3, 4 ... .

In the preferred embodiment, the motor is an A.C. motor, and the power reducing means comprises means for permitting full conduction of every first polarity half cycle, while restricting or inhibiting conduction of every opposite polarity half cycle. A first diode permits full conduction

of the first polarity (e.g. positive) half cycles to the motor. The first diode becomes reverse-biased during the opposite phase half cycles, thereby preventing conduction through the first diode. The first diode limits the power supplied to the motor by a factor of about a half.

In one embodiment, indicator means may be provided to give an indication when the power supply reducing feature of the apparatus has come into effect. For example, the indicator means may comprise a visual indicator, such as a light emitting diode (LED). Preferably, the LED comprises a second diode which is used to pass the opposite polarity (e.g. negative) half-cycles to the first diode. A series connected high resistance ensures that the current flow during these half-cycles is very small in order to avoid damage to the LED. Therefore, although current does pass through the motor during these (negative) half-cycles, the current is so small that substantially no useful power is communicated to the motor.

In the preferred embodiment, the series connection of the second diode (LED) and resistance is coupled in parallel with the first diode. The advantage of such an arrangement is that only a single pole thermally operated switch is required. In use, the second diode (LED) will flash on at the mains frequency (eg. 50 Hz or 60 Hz), but this will appear to the naked eye as constant illumination.

In a second aspect, the invention provides thermal protection apparatus adapted for use with an electric motor in the aforementioned assembly. The apparatus includes means for sensing a temperature associated with the motor in the assembly and for detecting when the temperature exceeds a predetermined threshold, and means responsive to a detected excessive temperature for reducing the level of electric power which is to be supplied to the motor, the reduced level of power being intended to avoid further overheating but being sufficient to permit at least limited operation of the electric motor.

In a preferred form, the thermal protection apparatus comprises a first diode for conducting first polarity half

cycles of an AC power supply, and a thermally operated switch for bypassing the first diode when the temperature is below the threshold, the switch contacts opening when the temperature threshold is exceeded. Preferably, the apparatus further comprises a second opposite polarity diode in combination with a high resistance for conducting opposite polarity half cycles of the AC power supply with reduced power. The second diode may be a light emitting diode.

In a closely related third aspect, the invention also provides a method of thermally protecting an electric motor, the method comprising sensing a temperature associated with the electric motor and detecting when the temperature exceeds a predetermined threshold, the method further comprising reducing the level of electric power supplied to the motor when an excessive temperature is detected, the reduced level of electric power being intended to avoid further overheating but being sufficient to permit at least limited operation of the electric motor.

The invention may be implemented in a dedicated hardware circuit and/or by means of a computer processor configured and programmed by software.

A preferred embodiment of the invention is now described by way of example only, with reference to the accompanying drawings, in which:-

Fig. 1 is a perspective view of an electric drill;

Fig. 2 is a circuit diagram of thermal protection apparatus used in the drill;

Figs. 3a and 3b are graphs illustrating power supplied to the motor and

Fig. 4 depicts a modified circuit for motor control.

Referring to the drawings, the drill 10 is of conventional outward appearance having a body 12 and a handle 14 with a trigger 16 that controls an ON/OFF switch 18 (not shown in Fig. 1) housed in the handle 14. The body 12 houses a motor 20 (not shown in Fig. 1) which drives a drive shaft 22 one end of which projects from the body 12. A chuck 24 is detachably mounted on the end of the drive

shaft 22. Power is supplied to the drill via a cable 26 from a conventional A.C. power supply at mains voltage.

The motor 20 includes a cooling fan blade (denoted by the symbol 28 in Fig. 2; not shown in Fig. 1) mounted on its drive shaft. The blade rotates as the motor operates, thereby creating a draught through the motor casing to cool the motor during operation. A vent 30 is provided near the front of the motor body 12 adjacent to the fan blade, and another vent 32 is provided at the rear of the body 12. The vents 30 and 32 allow air to be drawn into the body 12 for cooling, and expelled thereafter.

Referring especially to Fig. 2, a thermal protection circuit 34 is also contained within the body 12. The circuit 34 is coupled between one terminal of the motor 20 and one side of the power supply, in this embodiment, to the "live" (L) side of the power supply, via a live pole of the switch 18 which is of a dual-isolating type. The other terminal of the motor 20 is coupled directly to the other side of the power supply, in this embodiment, to the "neutral" (N) side of the power supply, via the neutral pole of the switch 18.

The circuit 34 comprises a first diode 36 coupled with a first polarity between an input node 38 and an output node 40. A series connection of a second, light-emitting, diode 42 and a resistance 44 is coupled in parallel with the first diode 36, the second diode 42 being in opposite polarity to the first diode 36. A thermally operated, normally closed, bypass switch 46 is also coupled in parallel with the first diode 36 between the input and output nodes 38 and 40. The switch 46 is mounted in close thermal contact with the motor, or with a part of the motor, as denoted by the broken line 48 and the symbol "°C". In this exemplary embodiment, the switch 46 is mounted adjacent to the fixed field lamination stack of the motor 20. The switch 46 is designed such that the switch contacts will open when the switch 46 is subjected to a temperature which exceeds a predetermined threshold, which threshold may be approximately 70°C. This represents the maximum recommended operating temperature for

the motor 20. The switch contacts will re-close as the temperature drops below the predetermined threshold.

In use, when the motor 20 is operating at a safe temperature (i.e. below the threshold temperature), the switch contacts of the switch 46 are closed, thereby shorting across the input and output nodes 38 and 40. The diodes 36 and 42 are therefore bypassed, and electric power is conducted unhindered to the motor, as illustrated in Fig. 3(a). In this figure, the vertical axis of each graph represents the voltage across the motor, and the horizontal axis represents time.

If the temperature of the motor 20 should exceed the threshold temperature, the switch contacts of the switch 46 will open, thereby removing the short circuit across the diodes 36 and 42 and forcing the electric power to be conducted by the diodes 36 and 42. Fig. 3(b) illustrates the effect of the diodes 36 and 42, and the resistor 44 in reducing the level of electric power supplied to the motor. On positive half cycles of the power, the first diode 36 will be forward biased, and will conduct the electric power to the output node 40. Therefore, positive half cycles of the power (50 in Fig. 3(b)) are supplied to the motor substantially unhindered. On negative half cycles, the first diode 36 will be reverse-biased, thereby preventing current flow through the first diode 36. Instead, the second diode 42 will become forward biased, and will thereby illuminate to indicate that the circuit 34 is operating to limit the supply of power to the motor. The series resistance 44 serves to limit the current through the second diode (LED) to a safe level to avoid damage to the diode. The value of the resistance 44 is very high compared to the DC resistance of the motor 20, whereby substantially all of the negative half-cycle power supply voltage is dropped across the resistance 44, and very little voltage is supplied to the motor. This is illustrated by the negative half-cycle portions 52 in Fig. 3(b), (the amplitude of the portions 52 is exaggerated slightly, for clarity). The effect of the circuit 34 is to restrict conduction of every

second half-cycle of the A.C. power to the motor. This reduces the power supply level by a factor of about a half, which is sufficient to ensure that the motor 20 is not fed enough power to perform further heavy work which might lead to overheating. On the other hand, the reduced power supply level is sufficient to enable the motor 20 to run with only a light load (or with no load at all), and thereby be cooled by the fan blade 28 which rotates as the motor 20 operates.

Once the motor 20 has cooled down to a safe temperature, the switch 46 will again re-close, thereby by-passing the diodes 36 and 42, and the resistance 44, to restore the full power supply level to the motor 20. Once the switch 44 becomes closed, no power will be conducted by the diodes 36 and 42; the second diode 42 will become extinguished to indicate the power-reduction feature is no longer in operation.

It will be appreciated that the invention is advantageous in protecting the motor once an over-temperature condition is detected, while still allowing limited operation of the motor. It will also be appreciated that the circuit in the preferred embodiment is uncomplicated and cheap to produce, yet is reliable and effective in use. The circuit also provides a visual indication of its status.

The first diode can be of any suitable type able to pass the full power (current) of each half cycle, and able to withstand reverse-bias at mains voltage. The second diode can be of any suitable low-voltage LED. The resistance should be selected to produce the appropriate forward voltage and current for the LED when forward biased. In the preferred embodiment, the first diode is a 3 Amp, 1000 Volt power-diode type, the second diode is a 5mA Red LED, and the resistance has a value 3.3 KΩ (2 watt) and a working voltage compatible with the mains voltage.

It will be appreciated that if no visual indication of the circuit status is required, then the second diode 42 and the resistance 44 could be omitted leaving only the first diode 36 in parallel with the switch 46. This would produce

virtually the same power reduction effect by conducting positive half-cycles to the motor unhindered, while inhibiting the negative half-cycles.

It will also be appreciated that the polarity of each diode could be reversed so that negative half-cycles were conducted substantially unhindered, while positive half-cycles were restricted or inhibited.

The drill may also include a speed controller for controlling the speed of rotation of the drill motor 20. For example, such a speed controller could be implemented by a gated diode rectifier, for example, a triac bidirectional rectifier. Such a controller could be interposed at any of the points labelled A, B and C in Fig. 2.

Fig. 4 illustrates an example of a modified motor circuit for the drill. The modified circuit is very similar to the circuit of Fig. 2, and in particular it includes the same thermal protection circuit 34. The main difference is that the modified circuit includes a triac speed/power regulator 54 coupled between the motor 20 and the neutral (N) side of the mains power supply. A speed control circuit 56 is coupled to the gate of the triac 54, and triggers controlled conduction of the triac to regulate the amount of power fed to the motor. The setting of speed control circuit 56 may be continuously variable, and controlled by a potentiometer, for example, coupled to the trigger 16 of the drill. Alternatively, the speed control circuit 56 may have one or more predetermined speed settings. In the exemplary embodiment shown in Fig. 4, a single-pole power supply switch 58 replaces the dual-pole switch 18 of Fig. 2 to emphasise that various switch arrangements may be used.

It will further be appreciated that a gated rectifier or other power regulating device could be used in the circuit 34, in order to reduce the power fed to the motor in the event of an overtemperature condition.

It is emphasised that the above description is merely illustrative of a preferred form of the invention, and that modifications of detail may be made without departing from the scope and principles of the invention.

CLAIMS

1. An assembly comprising an electric motor and thermal protection apparatus for the motor, the apparatus comprising means for sensing a temperature associated with the electric motor and for detecting when the temperature exceeds a predetermined threshold, and means responsive to a detected excessive temperature for reducing the level of electric power supplied to the motor, the reduced level of power being intended to avoid further overheating but being sufficient to permit at least limited operation of the motor.

2. An assembly according to claim 1, wherein the motor includes means for cooling the motor as the motor operates.

3. An assembly according to claim 2, wherein the means for cooling the motor comprises a fan blade carried on or operated by the motor shaft.

4. An assembly according to claim 1, 2 or 3, wherein the apparatus further comprises means for restoring the normal electric power supply level to the motor when the means for sensing the temperature detects that the temperature has dropped below the predetermined threshold.

5. An assembly according to any preceding claim, wherein the motor is driven by A.C. power or by pulse-modulated D.C. power, the power having a duty cycle, and wherein the means for reducing the power level supplied to the motor comprises means for reducing the duty cycle of the electric power.

6. An assembly according to claim 5, wherein the means for reducing the power level supplied to the motor comprises means for restricting or inhibiting conduction of selected conduction portions of the electric power.

7. An assembly according to claim 6, wherein the electric

power comprises A.C. power, and wherein the means for reducing electric power comprises means for enabling conduction of every first polarity half cycle, and means for inhibiting or restricting conduction of every opposite polarity half cycle.

8. An assembly according to claim 7, wherein the means for reducing electric power comprises a first diode.

9. An assembly according to claim 8, wherein the means for reducing electric power further comprises a series connection of a second diode and a resistance, the series connection being coupled in parallel with the first diode, the second diode having an opposite polarity to the first diode.

10. An assembly according to claim 9, wherein the second diode is a light emitting diode (LED).

11. An assembly according to any preceding claim, wherein the means for sensing the temperature and for detecting when the temperature exceeds a predetermined threshold comprises a thermally operated bypass switch for bypassing the power reducing means when the temperature is below the predetermined threshold.

12. Thermal protection apparatus adapted for use in an assembly according to any preceding claim, the apparatus comprising means for sensing a temperature associated with the motor of the assembly and for detecting when the temperature exceeds a predetermined threshold, and means responsive to a detected excessive temperature for reducing the level of electric power which is to be supplied to the motor, the reduced level of power being intended to avoid further overheating but being sufficient to permit at least limited operation of the motor.

13. A method of thermally protecting an electric motor, the

method comprising sensing a temperature associated with the electric motor and detecting when the temperature exceeds a predetermined threshold, the method further comprising reducing the level of electric power supplied to the motor when an excessive temperature is detected, the reduced level of electric power being intended to avoid further overheating but being sufficient to permit at least limited operation of the electric motor.

14. An electric drill substantially as hereinbefore described with reference to the accompanying drawings.

15. Thermal protection apparatus for an electric motor, the apparatus substantially as hereinbefore described with reference to figures 2 and 3 of the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

12

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Relevant Technical Fields (i) UK Cl (Ed.M) H2J (JDSA, JCP, JEP) (ii) Int Cl (Ed.5) H02H (7/08, 9/00)	Search Examiner B J EDE Date of completion of Search 21 MARCH 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASES: WPI	Documents considered relevant following a search in respect of Claims :- 1-15

Categories of documents

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&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2248987 A	(MERCEDES-BENZ) See 4.2 Figure 1	1, 4-6, 12, 13
X	GB 2145678 A	(AISIN SEIKI KK) See TH, DM Figures 1 and 2	1, 4-6, 12, 13
X	GB 2078028 A	(METABOWERKE) See 1, 3, 4, 9 and 11	1-8, 12, 13
X	GB 1590290	(GENERAL ELECTRIC) See 11a, 11, 13, 14, 16 Figures 1 and 2	1-8, 12, 13
X	GB 1015225	(TECUMSEH) See 34 Figure 1	1-6, 12, 13
X	WO 87/04276 A1	(ARENDS) Whole document relevant	1-6, 12, 13

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